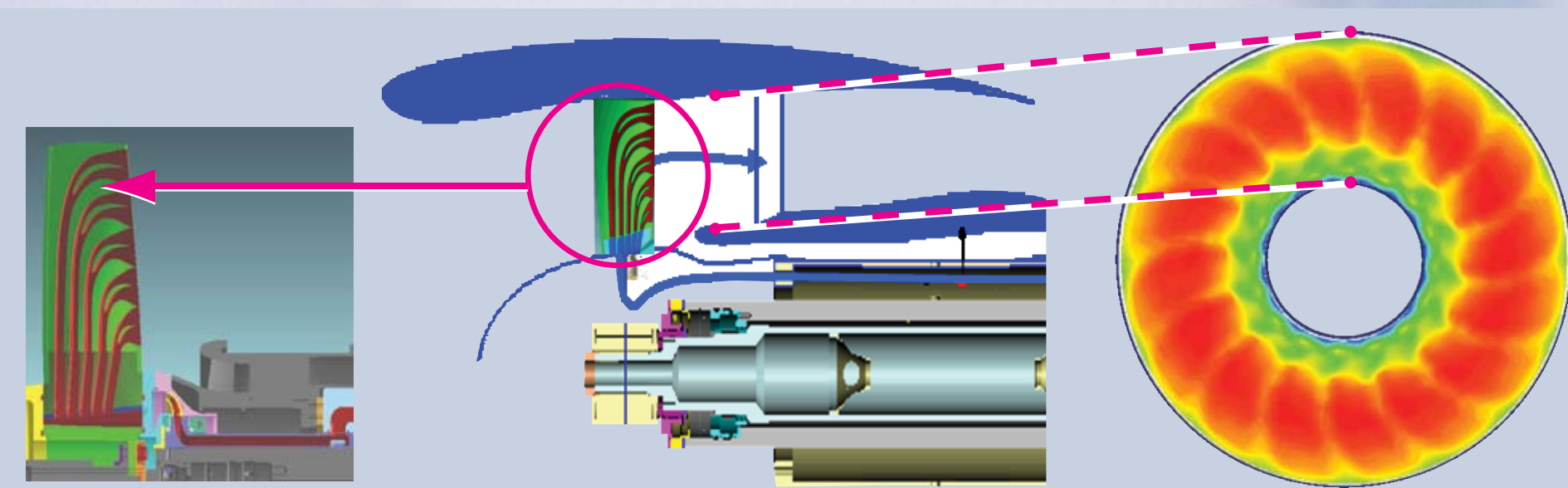


Flow Control Opportunities for Propulsion Systems

The advancement of technology in gas turbine engines used for aerospace propulsion has been focused on achieving significant performance improvements. At the system level, these improvements are expressed in metrics such as engine thrust-to-weight ratio and system and component efficiencies. The overall goals are directed at reducing engine weight, fuel burn, emissions, and noise. At a component level, these goals translate into aggressive designs of each engine component well beyond the state of the art.

FAN

The fan must provide increased loading capability to achieve higher bypass ratio and increased thrust. Fan noise in the forward and aft directions must be reduced during takeoff and landing. This must be accomplished without unduly increasing rotational speed and while maintaining high efficiency as well as adequate stable operability margin.

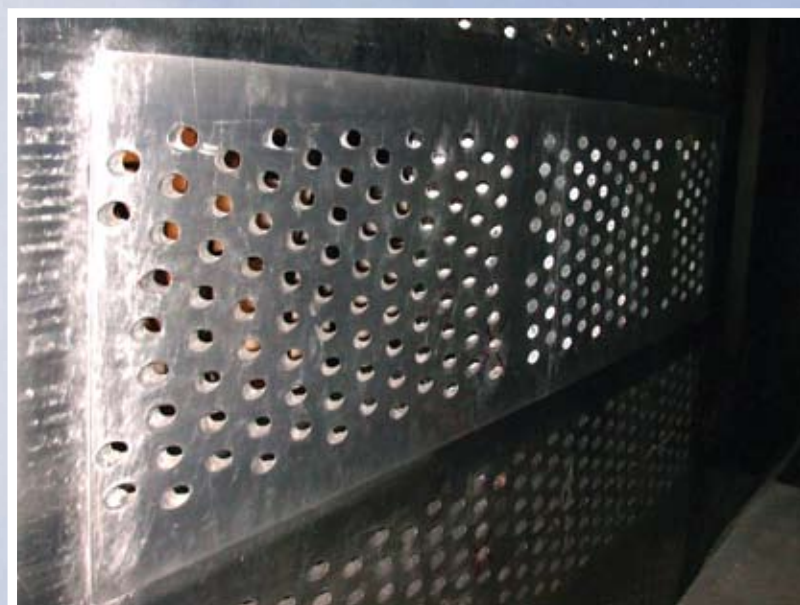


Fan Trailing-Edge Blowing for Acoustic Suppression

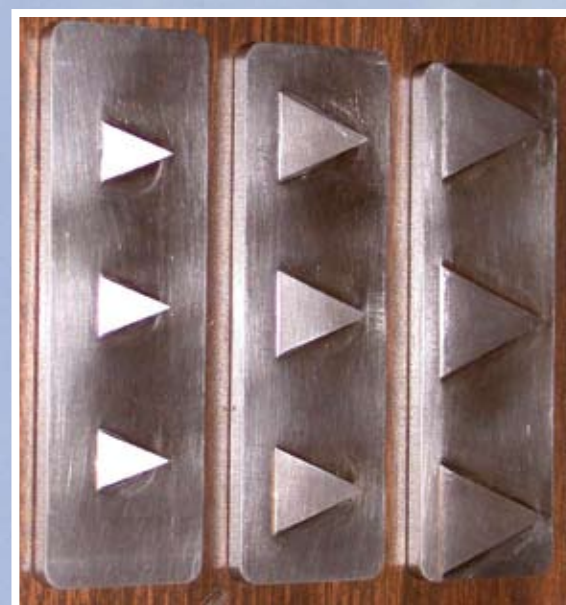
Reduce wake velocity deficit and acoustic interaction with the exit guide vane

INLET

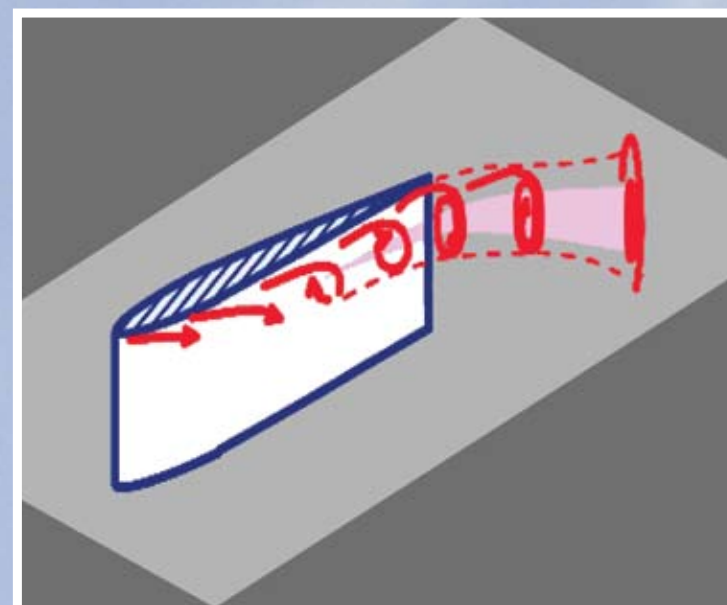
The inlet must provide required propulsion system airflow with maximum aerodynamic efficiency, dependable operability and minimum complexity, distortion, acoustics, drag, weight, and cost for increasingly integrated and aggressive aircraft designs.



Boundary-layer bleed



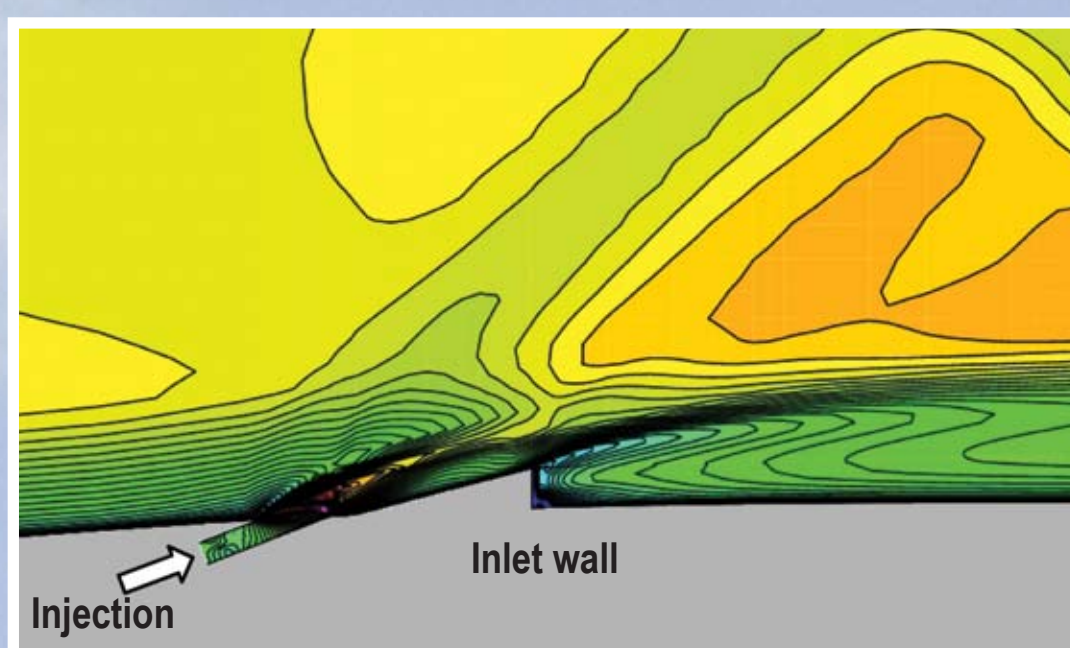
Ramps and microramps



Vanes and microvanes

Passive Boundary-Layer Control

Control boundary-layer growth and separation

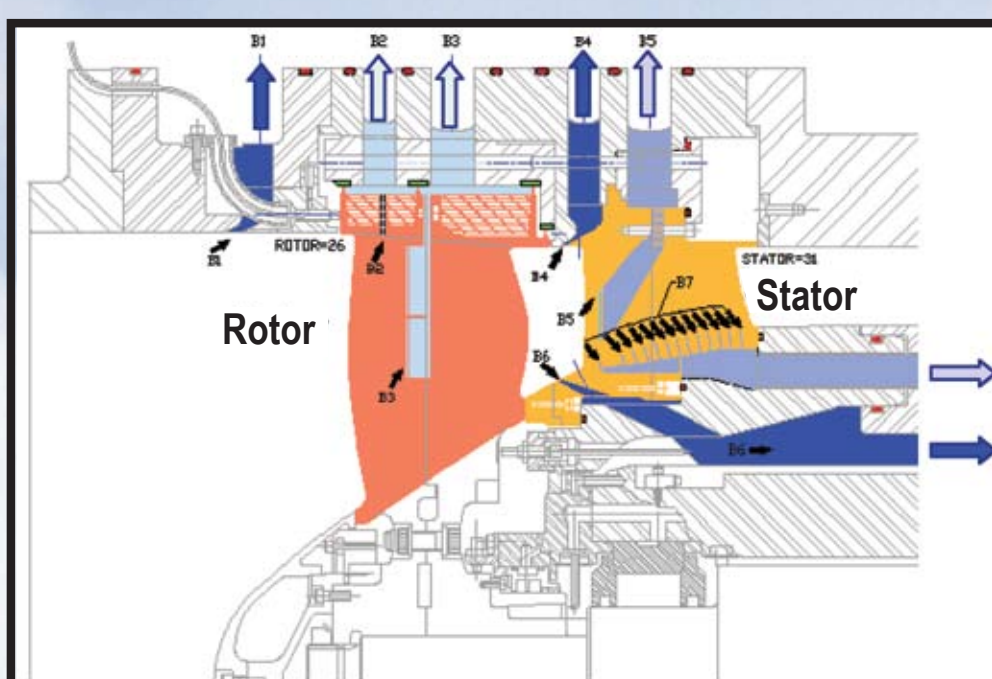


Microramps With Injection

Prevent shock-induced boundary-layer separation without boundary-layer bleed

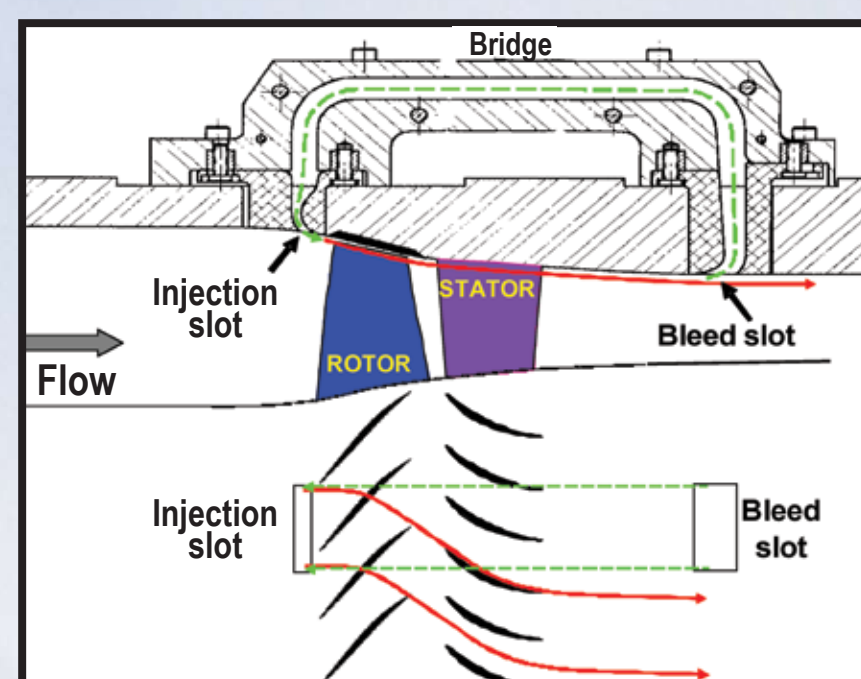
COMPRESSOR

The compressor must raise compressive efficiency by increased airfoil loading and improved control of three-dimensional flow near the endwalls. This must be accomplished while maintaining or improving stable operability margin and without unduly increasing rotational speed.



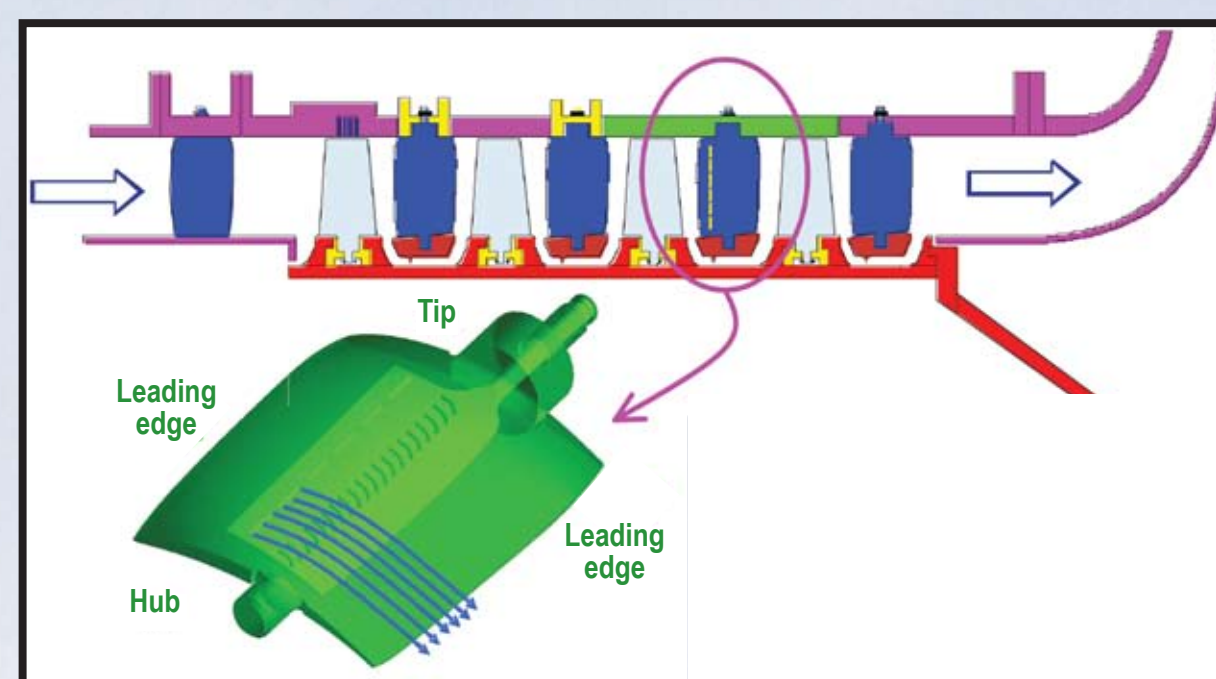
Aspirated Compressor

Demonstrate ultrahigh loading capability for increased operability and weight reduction



Rotor Tip Injection With Recirculation

Decrease incidence and loading at the tip to enable overall increased blade loading and stable range extension

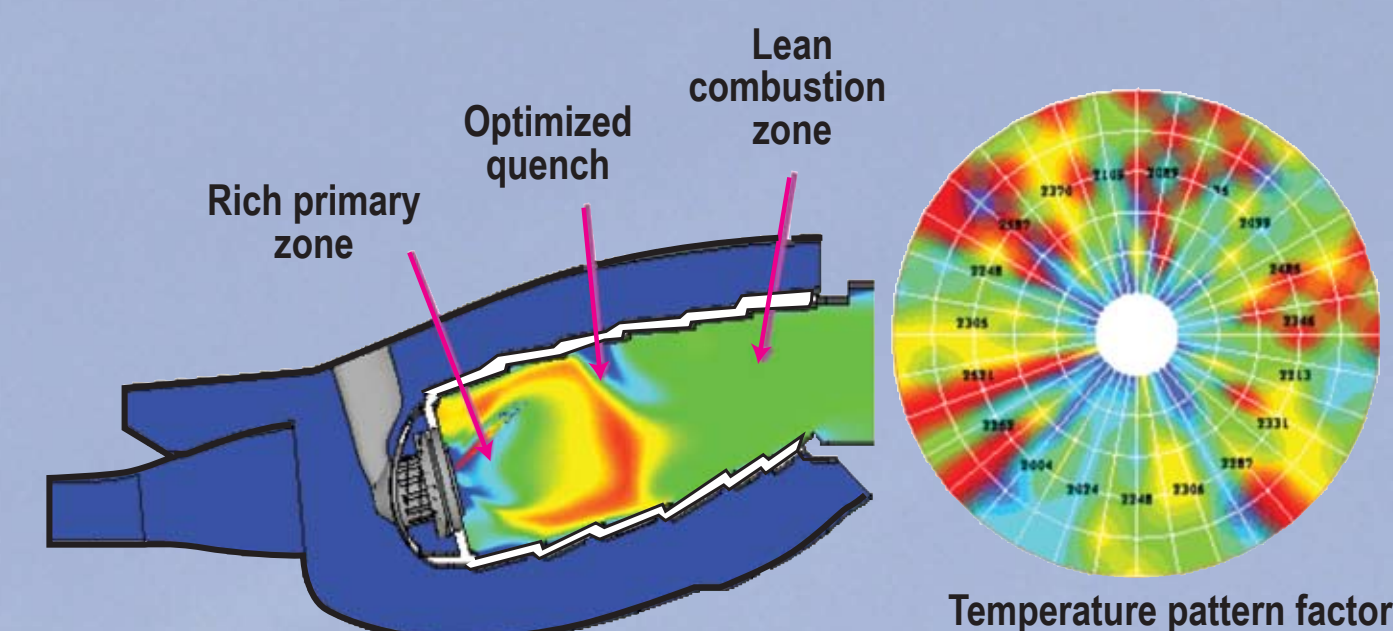
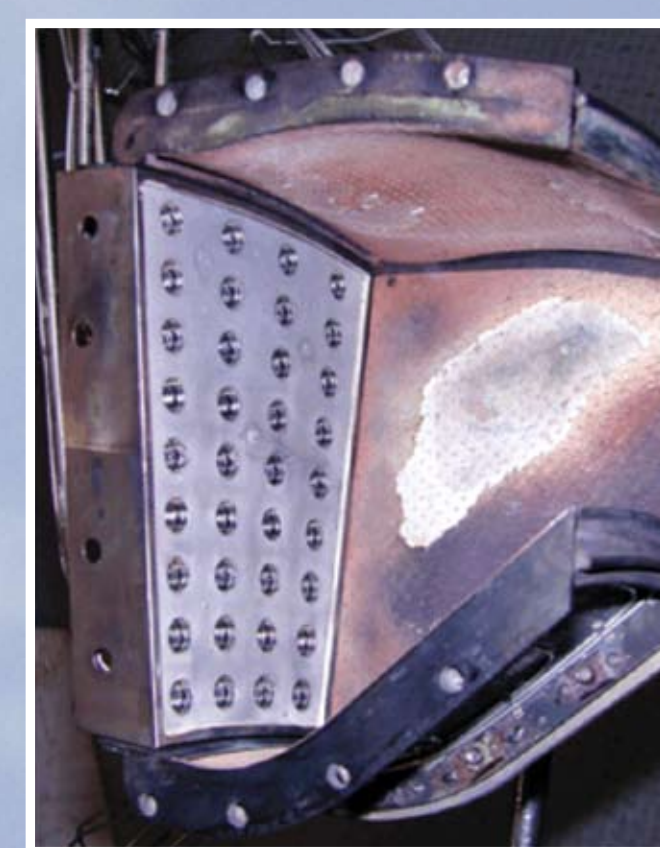


Stator Separation Control

Reduce separation to increase vane loading and improve operability at off-nominal conditions

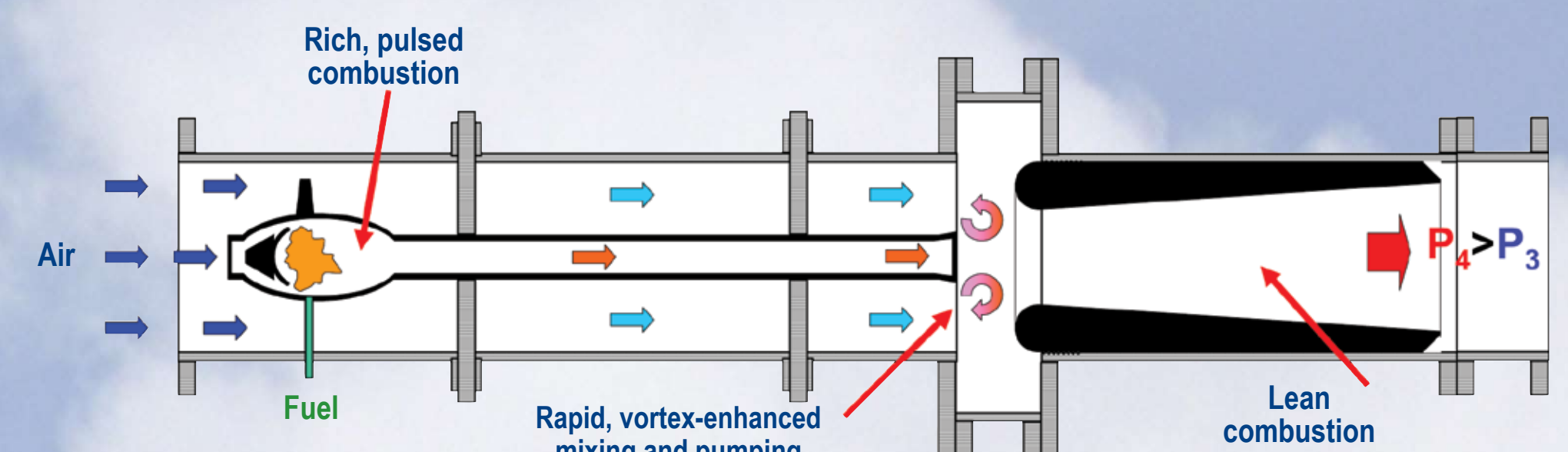
COMBUSTOR

The combustor must deliver targeted emission reductions through more efficient combustion at lower peak temperatures in order to eliminate or significantly reduce NO_x, CO₂, and unburned hydrocarbons.



Low-Emission Enabling Control

Active suppression of thermoacoustic pressure oscillation, NO_x production, and temperature variation

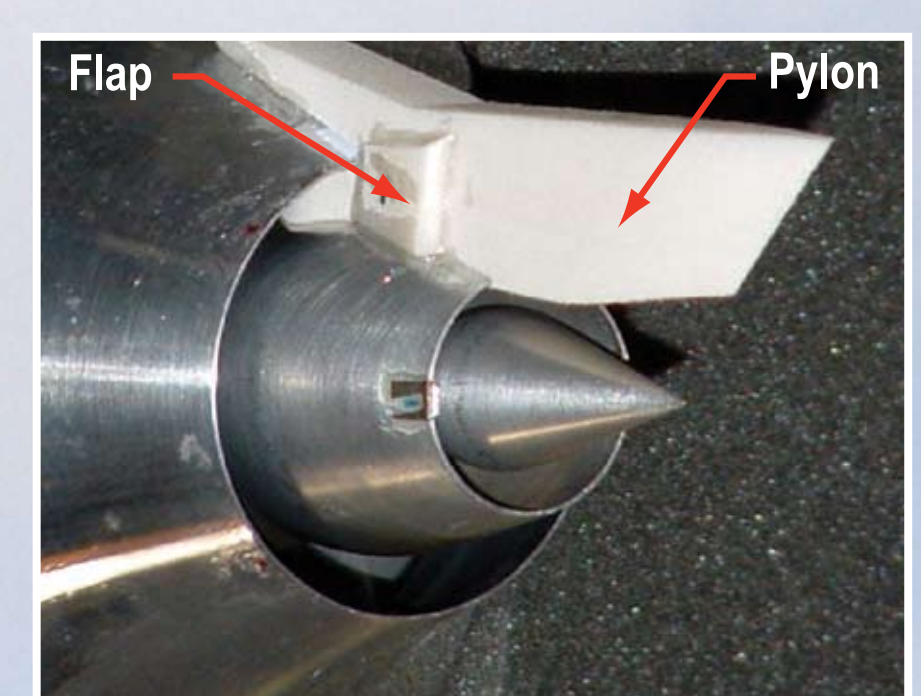


Ejector-Enhanced Pulsed Combustors

Pressure-gain combustor with rich-burn, quick-quench, lean-burn (RQL) emissions potential

NOZZLE

The nozzle must maximize thrust but be able to diffuse and expand the flow in a much smaller region, while maintaining minimum total pressure loss and simultaneously satisfying operability, cost, weight, signature, life, and acoustic requirements.



Pylon Flaps

Deflection of bypass flow around jet reduces ground-directed noise

TURBINE

The turbine must provide improvements in power output through improved airfoil loading and lower aerodynamic loss. Increased cooling effectiveness will have dramatic impact on reduction in core size. These must be accomplished within material and structural limits and at high aerothermodynamic efficiency.



Film Cooling Computational Fluid Dynamics

Modification of hole pattern and geometry can increase film cooling effectiveness and reduce cooling flow requirements

